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(71)(72) Applicants and Inventors: GAJDA, Remigiusz [PL/PL]; Franciszkańska 3 m.26, PL-00-233 Warszawa (PL). STEPIEŃ, Paweł [PL/PL]; Batumi 6 m.43, PL-02-760 Warszawa (PL).

(74) Agent: DRESZER-LICHAŃSKA, Hanna; Deresz and Dreszer, Al.Niepodległości 188 B, PL-00 608 Warszawa (PL).

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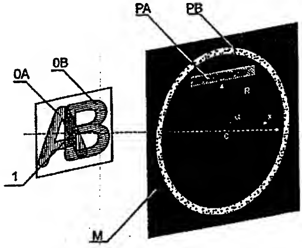
(54) Title: OPTICALLY VARIABLE DEVICE (OVD) AND A METHOD OF RECORDING OVD AND AN OVD RECORDER



(57) Abstract

In an optically variable device consisting of pixels at least one pixel (1) is a graphical reproduction of a phase of a Fourier transform of a map (M) of viewing angles defined for each such pixel (1). An optically variable device is recorded through illuminating, upon the opening of a shutter (2), with an expanded and convergent beam (L) of laser light, an image (6) of the pixel map, obtained as a graphical reproduction of a phase of the Fourier transform of the map of viewing angles, and the map is then reduced to a desired size with a lens (4). Subsequently, the shutter (2) shuts off the laser light beam (L) and the photosensitive material where an optically variable device is recorded, is moved on to the next pixel with the use of an XY moving stage (5) and the procedure is repeated. A recorder of optically variable devices is provided with an image (6) of the pixel map between an expander (3) of the laser light beam (L) and the lens (4).

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Optically variable device (OVD) and a method of recording OVD and an OVD recorder.

FIELD OF THE INVENTION

The subject of the present invention is an OVD and a method of recording said OVD and a recorder realising this method.

BACKGROUND OF THE INVENTION

OVDs in the form of diffractive structures and holograms with resolution of some 1000 line pairs per mm typical for such elements are frequently used for many purposes, e.g. as authenticating elements. Mosaics of diffraction gratings are good examples of such elements. One of the best known types of OVDs is a "Kinegram" disclosed in Swiss patent 04576. Images visible on the kinegram smoothly change depending on the viewing angle. This effect is achieved by dividing the element plane into pixels which are further divided into a number of fragments, imperceptible to the naked eye, the fragments being assigned to particular images. Fragments of different pixels corresponding to a given image are provided with straight diffraction gratings in such a manner that all there pixels diffract light into one direction, so this image is visible at a proper viewing angle. Where the viewing angle is changed, pixel fragments corresponding to another image become visible. The main disadvantage of such OVDs is a limitation of the number of images which may be recorded on one OVD to a certain predefined number and a limitation of resolution used in OVD recording. In particular it is impossible to produce this way an OVD containing smoothly changing high resolution images.

In Japanese patents JP 26684/91 and JP 79080 are described methods of recording OVDs in which curvilinear diffraction gratings with precisely defined grooves shapes are used. This enables to obtain desired effects of optical variability. It is also possible to record OVD using lithographic techniques. Its main disadvantage is a high cost of the process and relevant equipment to carry it out.

Another method of recording OVD is disclosed in US Patent 5262879. In this method, a flat image scanned into the computer memory is converted into diffraction grating pixels forming an OVD. This grating is recorded pixel by pixel on a photosensitive

surface using an optical laser recorder. The disadvantage of this method is its small flexibility, i.e. a limited range of potential OVDs possible to make.

The method described in the present invention eliminates the disadvantages mentioned above.

OVDs may be recorded with the use of devices, consisting of a laser, a shutter, an optical beam expander, a rotationally mounted diffraction grating, a convergent lens in whose focal point a diaphragm in the form of a dark point shading undiffracted light is provided. The other lens produces a properly reduced image of the grating with doubled line pairs on the photosensitive material located on a computer-driven XY moving stage. A disadvantage of such a recorder is a limited range of potential OVDs, which may only contain fixed size diffraction gratings with different angular orientations.

The recorder described in the present invention eliminates the disadvantages mentioned above.

SUMMARY OF THE INVENTION

The subject-matter of an OVD is that at least one of its pixels is a graphical reproduction of a phase of a Fourier transform of the map of viewing angles defined for each such pixel.

Advantageously, at least one such pixel lies near a rainbow hologram.

The subject-matter of the method of recording OVD is that after opening the shutter an expanded and convergent beam of the laser light illuminates an image of the pixel map obtained as a graphical reproduction of a phase of a Fourier transform of the map of viewing angles. The map is then photoreduced using a lens to proper size, the shutter shuts off the laser light and the photosensitive material where an OVD is recorded is moved to the position of the next pixel using an XY moving stage and the procedure is repeated. Advantageously, the convergent beam of the laser light is, after passing through the image of the map of the pixel, modified by a filter, lying in a plane where the Fourier transform of map is formed by lens. Advantageously, the Fourier transform of the map of viewing angles is calculated using the iterative Fourier transform algorithm.

The subject-matter of the OVD recorder is that between the expander and the lens an image of map of the pixel is provided. Advantageously, in the beam-expander focal plane there is a filter modifying the Fourier spectrum of the pixel image.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is shown in an embodiment presented schematically on the drawing where Fig.1 shows an OVD and a map of viewing angles for one pixel, Fig. 2 shows the method of an OVD recording and Fig.3 shows an OVD recorder realising the method.

DETAILED DESCRIPTIONOF THE INVENTION

An optically variable device (OVD), (Fig.1) contains a diffractive structure consisting off small pixels 1 which are pure phase Fourier holograms of maps M of viewing angles of these pixels. Every such map M contains an image composed of light points against a black background. An angle α between a segment of a line from the middle O of the map of angles to any of the light points and an 0X axis represents one direction of the element's viewing, the length R of this segment represents spatial frequency for this pixel and the angle of the element's inclination needed to view this pixel, and the value of the point's brightness represents a relative intensity of light diffracted in this direction and spatial frequency. A complete image composed of such points forms a map of viewing directions, in which the pixels diffract light when illumined with monochromatic light. For example, an OVD containing two, partially overlapping images OA and OB, which should be visible within different ranges of viewing angles PA and PB contains at least 3 types of pixels 1:

1. the pixels contained only in the OA image area, whose map of viewing angles contains only the light area PA.
2. the pixels contained only in the OB image area, whose map of viewing angles contains only the light area PB,
3. the pixels contained in the common part of the OA and the OB image areas, whose map of viewing angles contains the light area being the sum of areas PA and PB.

The map of viewing angles for each pixel is represented in the computer by a matrix of complex numbers whose amplitudes are equal to brightnesses of corresponding points of the map of viewing angles, and phases are assigned in the form of a so called diffuser, being a matrix of complex numbers with amplitudes equal to 1, composed in a way securing maximum uniformity of the distribution of values of amplitude in the Fourier transform of this matrix. The simplest diffuser is the random diffuser, being a matrix of complex numbers with randomly assigned arguments. The matrix composed in this way is then Fourier transformed, and from the resulting complex matrix only its phase (argument) values are

stored in memory. The phase values matrix is then graphically represented as an image of the pixel, where the subsequent grey scale levels represent subsequent phase values. Typically, this pixel image is composed of irregular lines. Distances between these lines are more or less constant, especially in the case of a map containing only the PA area. The image of the pixel is recorded, in a proper scale (giving the lines resolution of some 600-1500 lines/mm), on a relief photosensitive material (photoresist), where the gray levels of the pixel map are reflected in the relief depth.

A colored, flat, optically invariable image (e.g. graphics) or a set of such images is converted to an OVD consisting of pixels described above in a way ensuring the best readability after illumination with white light from proper directions. In this example, an image QA is visible at a constant vertical inclination of the OVD within a wide range of horizontal inclination angles, and an QB image is visible when the OVD is properly inclined in relation to the light source and rotated in its plane at any value.

Besides the pixels being Fourier holograms of maps of viewing angles, the OVD may contain a rainbow hologram, commonly used as an authenticating element. The rainbow hologram may be recorded as an analog hologram in a traditional optical arrangement or as a computer generated rainbow hologram using a computer controlled recorder described later. Inclusion of a rainbow hologram in the OVD described above enhances its esthetical value.

The method of recording of an OVD resides in the following:

1. A Fourier transform of the map of viewing angles is calculated and a gray scale map of its phase (argument) being a pixel image 6 is printed on a transparence or displayed on a spatial light modulator,
2. the pixel image 6 is then illuminated with an expanded, convergent beam L of laser light,
3. using the lens 4, the pixel map is reduced to proper lines density on a photosensitive material,
4. laser light beam L is shut off using a shutter 2, and the photosensitive material is moved to the position of the next pixel using an XY moving stage 5,
5. the shutter then opens and the procedure is repeated until all the pixels of OVD are exposed.

It is advantageous that the laser beam L after passing through the pixel map image 6 is modified by a filter 7. The filter located in the laser beam focal plane, where the map of

the pixel viewing angles is optically reproduced, stops the light corresponding to angles in which OVD should not be visible.

It is also advantageous, when the Fourier transform (FT) of the map of viewing angles (MVA) is calculated using an iterative Fourier transform algorithm (IFTA), to obtain a uniform value of the transform amplitude, which is impossible with the use of a direct way of the Fourier transform calculation. In the IFTA the complex matrix of the same size as MVA is filled with complex numbers whose amplitudes correspond to MVA values and random number are assigned to arguments (a random diffuser is applied). Then the direct FT is applied and the amplitudes of resulting complex matrix elements are uniformised (i.e. they all receive the same value, usually 1) without changing their arguments. Subsequently, the reverse FT is calculated (thus returning to the MVA domain) and the amplitudes of matrix elements are filled with MVA values with no change to elements phases. This loop is repeated several times (usually 5-20) and completed after the direct FT calculation producing a complex matrix with highly uniformised amplitudes of elements and very good quality of MVA restoration.

The OVD recorder, Fig.3, consists of a laser which is the source for the beam L of monochromatic light. Behind (or within) the laser there is a shutter 2 and a beam expander 3, which forms an expanded, convergent beam of laser light with its focal point located in front of the lens 4 photoreducing the image 6 of the pixel map, which is located between the expander 3 and the lens 4, on the photosensitive material located on the XY moving stage. The recorder is controlled by an external computer opening the shutter 2 and controlling the movement of the XY stage.

The recorder may also contain the filter 7 located in front of the lens 4 in the focal plane of the expander 3 . This filter modifies Fourier spectrum of the image of the pixel thus modifying MVA restoration.

CLAIMS

1. An optically variable device consisting of pixels characterized in that at least one of this pixels (1) is a graphical reproduction of a phase of a Fourier transform of the map of viewing angles defined for each such pixel (1).
2. An optically variable device according to claim 1, characterized in that at least one such pixel lies near a rainbow hologram.
3. A method of OVD recording characterized in that after the opening of the shutter (2) an expanded and convergent beam (L) of laser light illuminates an image (6) of the pixel map obtained as a graphical reproduction of a phase of a Fourier transform of the map of viewing angles and using a lens (4) this map is photoreduced to a desired size and the shutter shuts off the laser light beam (L); then the photosensitive material where an OVD is recorded is moved to the position of the next pixel using an XY moving stage (5) and the procedure is repeated.
4. A method according to claim 3 characterized in that the convergent beam (L) of the laser light, after passing through the image (6) of the map of the pixel, is modified by a filter (7), lying in a plane where the image (6) Fourier transform is formed by lens.
5. A method according to claim 3 characterized in that the Fourier transform of the map of viewing angles is calculated using an iterative Fourier transform algorithm.
6. An OVD recorder, containing a laser, a shutter, the beam expander, lens and a XY moving stage characterized in that there is an image (6) of the pixel between a beam expander (3) and the lens (4).
7. An OVD recorder according to claim 3 characterized in that in front of the lens (4) there is the filter (7) modifying the Fourier spectrum of pixel image (6).

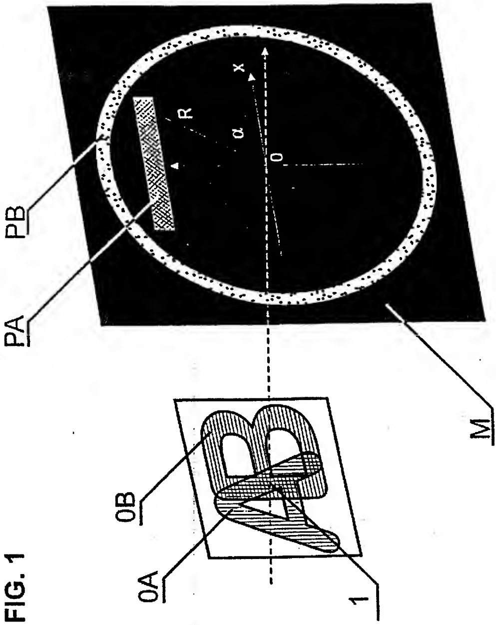

FIG. 1

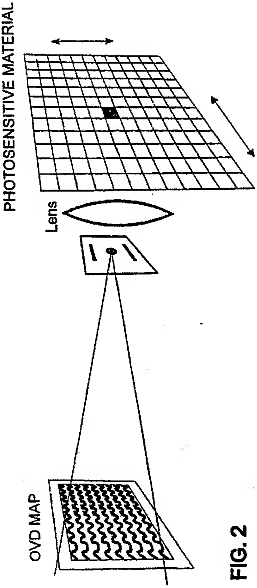

FIG. 2

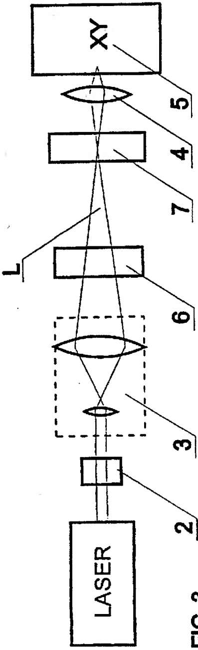

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G03H1/26 G02B5/18 G02B27/44

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G03H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 91 03747 A (COMMW SCIENT IND RES ORG) 21 March 1991 see page 2, line 11 - page 4, line 32 ---	1
A	EP 0 375 833 A (LANDIS & GYR BETRIEBS AG) 4 July 1990 cited in the application see claim 1; figures ---	1
A	US 5 262 879 A (DAVIS FRANK S) 16 November 1993 cited in the application see claims; figures -----	1,3,6

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Information on patent family members

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